Evaluating Education: Analyzing Pre-Service Teachers' Assessments in Light of Equity Pedagogy and Mathematical Practices

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Abstract

The purpose of this study was to assess pre-service teachers' application of equity pedagogy and mathematical practices in their evaluation of children's mathematical content knowledge and reasoning skills. This agenda is in response to a call from the national mathematics education research community to pursue such connections. In this study, the researchers utilized two tools: the Learning about Mathematics and Pedagogy (LAMP) survey and a series of reflective prompts. These tools were used to survey pre-service teachers (PSTs) from an Early Childhood Education program at a regional campus of a large Research I institution. The survey and reflective prompt results suggest that these PSTs struggled to incorporate certain aspects of equity pedagogy and mathematical practices in their assessments of children's mathematical content knowledge and reasoning skills. The data collected suggests these PSTs are not instinctively choosing to seek out and give weight to the arguments of their own students. Instead, it appears that they are using a narrow perspective in approaching mathematical content as well as in interpreting their students' logical reasoning without input from the students themselves. However, these results improved significantly upon a second administration of the survey and reflective prompts tool following a Math Methods course taken by the PSTs as part of their undergraduate program. We conclude that the PSTs' initial perspective came as the result of an incomplete content knowledge, given they were more inclined to make equitable choices in their responses to students' work when they themselves demonstrated a deeper understanding of the content that was being taught.

Evaluating Education: Analyzing Pre-Service Teachers' Assessments

in Light of Equity Pedagogy and Mathematical Practices

. The field of mathematics education has come to a focus on equity through various routes and over multiple decades. Equity can be defined as the quality of impartiality that allows for all voices to receive the same weight and be viewed with equal importance. A teacher's classroom is equitable if the teacher creates a just and impartial environment through a variety of means, particularly by utilizing instruction and assessment strategies that align with the principles of Equity Pedagogy. This study investigates the pedagogical practice connections made by pre-service teachers between Equity Pedagogy and the Common Core Standards for Mathematical Practices.

Literature Review

Over the years, mathematics education has increased its focus on equity as a result of the actions of various leaders in the field. The National Council of Teachers of Mathematics (NCTM) released the Curriculum and Evaluation Standards for School Mathematics in 1989, where they led the field with the inclusion of equity; and their Principles and Standards in 2000, where equitable practices are included. In response, the field has addressed equity in teaching mathematics in many ways in the decades following the release of these documents (e.g. Boaler, J., 2006; Boaler, J. & Staples, M., 2008; Erchick, D. B., Dornoo, M., Joseph, M. &Brosnan, P., 2010; Joseph, M. P., 2013; Martin, D. B., 2003; Martin, D. B., Gholson, M. L. & Leonard J., 2010; Nasir, N. S., 2002; National Council of Teachers of Mathematics, 2014; Sommerfeld, M. S. & Cobb, P., 2006). However, although these and other mathematics education scholars have progressed the field in terms of addressing equity and pedagogy (e.g. Joseph, 2013), what is still lacking is a way to connect the demands of the curriculum (such as state standards based on the

Common Core for Mathematics) and the implications of the Common Core Mathematical Practices; with teachers' understanding of pedagogical practices focused on an equity agenda. Most recently, Bartell et al. (2017) have put forth a call to the mathematics education research community to pursue inquiry around such connections, particularly focused on Equity Pedagogy and the Common Core Mathematical Practices. Since it is the mathematical practices that distinguish the Common Core from previous state and national standards, the pursuit of this inquiry is timely.

Procedure

In this study, the researchers used two tools to survey pre-service teachers (PSTs) from an Early Childhood Education program at a regional campus of a large Research I institution. The first tool, the Learning about Mathematics and Pedagogy (LAMP) survey, was developed by the primary research mentor, Dr. Diana Erchick. It is composed of forced response items and narrative explanations centered on 10 samples of children's mathematical work, two of which were studied in detail by the researcher, Olivia Britt. Additional data was derived from the second tool, reflective prompts that encouraged PSTs to describe their perceived growth by comparing their LAMP responses before ("pre-responses") and after ("post-responses") taking a Math Methods course. It should also be noted that the researcher and the research mentor were working at the same university as the PSTs, but were provided with de-identified data after both the tools had been administered. Thus, the researcher had no relationship with the subjects prior to or during the research and analysis detailed in this study.

To provide additional context, the Math Methods course taken by the PSTs is a required course their Early Childhood Education (ECE) program, and it is one of many courses taken in their junior year. It is important to note that the university's Equity and Diversity and Special

Education courses, which are both required by the ECE program, are taken in the semesters following the completion of this Methods course. Therefore, the PSTs are not enrolled in an equity-specific course concurrently with this Methods course and, though only about one-fifth of the course is explicitly equity-focused, the instructor of the Methods course has built a reputation of bringing an equity lens to her pedagogical practice over her twenty years of teaching this course. Through this course, the students are also taught specifically about the Common Core Mathematical Practices. Additionally, learning objectives to support the CCMP were required components of every lesson plan. Thus, through this course, the PSTs gain a considerable amount of knowledge regarding both the CCMP and equity in the context of mathematical pedagogy, knowledge that is not otherwise available to them in their program until after the completion of this course.

Data Analysis

To analyze the data, the researcher coded responses to two of the LAMP mathematical work samples with codes that identify selections in the data as representing one or more of Joseph's (2013) Equity Pedagogy Categories (EPC), the Common Core Mathematical Practices (CCMP) (2010), or as representing aspects of both the EPC and the CCMP. The researcher also coded the responses based on if a response was in direct opposition to the EPC or the CCMP, representing this with an X after the individual code. The EPC and CCMP codes are presented below. To ensure the validity of this coding process, the researcher and the research mentor initially coded one subset of the data separately, then compared their results and discussed any discrepancies in their coding decisions. To increase the consistency and credibility of the results, they ultimately agreed on a single interpretation as the research focus. This review served as a means to enhance the trustworthiness of the analysis prior to moving forward with the research.

EPC Codes

ETL: Explicit **T**alk about the meaning and use of mathematical **L**anguage
ETR: Explicit **T**alk about ways of **R**easoning
ETMP: Explicit **T**alk about **M**athematical **P**ractices
EST: Explicit **S**tudent **T**asks and work
IT: Quality of **I**nstructional **T**ime spent on mathematics
EDC: Encouragement of a **D**iverse array of mathematical **C**ompetencies
AU: Autonomous student work opportunities
RWP: Real-**W**orld **P**roblems or examples
ESE: Emphasis of **S**tudent **E**ffort and message that effort will eventually pay off
EE: Expressed **E**xpectation that everyone will be able to do the work
OCK: Opportunity for **C**o-construction of **K**nowledge
SVA: Fore-grounding **S**tudent Voice and **A**gency
EMT: Explicit attention to **M**utual **R**espect
ECT: Encouraging **C**ritical **T**hinking

CCMP Codes

MSP: Make **S**ense of problems and **P**ersevere in solving them
RAQ: Reason **A**bstractly and **Q**uantitatively
CACR: Construct viable **A**rguments and **C**ritique the **R**easoning of others
MM: Model with **M**athematics
UTS: Use appropriate **T**ools **S**trategically
AP: Attend to **P**recision
LUS: Look for and make **U**se of **S**tructure
LER: Look for and **E**xpress **R**egularity in repeated reasoning

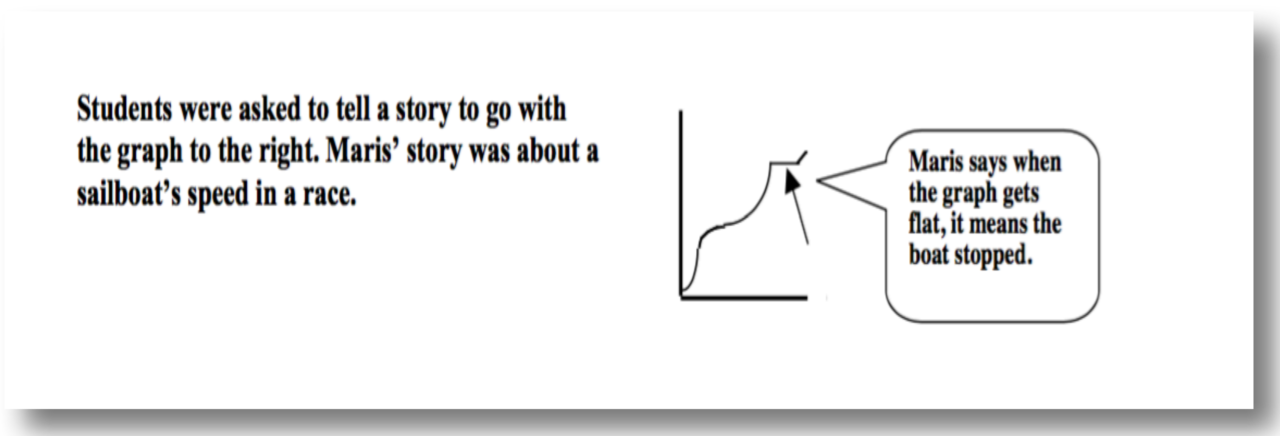
Student Problems

Two out of the ten LAMP survey questions were chosen to be the focus of this study: Maris' rate of change problem and Mike's subtraction problem. The researcher selected these two in particular for comparison because they address very different content. Comparing these two problems allowed for the researchers to ensure that the results of the study would not be content-specific but rather would be consistent regardless of the mathematical content addressed in the problem. Another reason for choosing these two problems was the substantial amount of data from them available through the reflective prompts tool, seeing as many PSTs decided to reflect on their growth with regards to these two problems in particular.

Maris

LAMP survey. The first problem chosen from the LAMP survey for this analysis is a problem that centers on the idea of rate of change. The PSTs were provided with the information below, and they were then asked how they would represent what Maris understands and does not understand from Maris' response to the problem. The teachers were also asked what next steps they would take to further Maris' understanding of the material.

Maris' Rate of Change Problem



Seeing as there are no labels on the axes of this graph and the instructions to the students were very open-ended, there are a number of ways in which Maris' idea could be interpreted. For instance, Maris could have considered the x-axis as representing time and the y-axis as representing distance from a point of reference, such as the race's starting line. This would still represent speed, which is the ratio of distance traveled over time, and would make Maris' explanation valid. Another interpretation would be that Maris was attempting to represent speed over time, with time as the independent variable along the x-axis and speed as the dependent variable along the y-axis. This would make Maris' explanation incorrect because a flat line on the graph would represent a constant speed. A knowledge of the content and a thorough analysis of the problem are both required in order for a reader to realize these multiple possible interpretations.

After analyzing the data, the EPC codes which emerged as lacking in the work of the PSTs were Encouragement of a Diverse Array of Mathematical Competencies (EDC) and Fore-grounding Student Voice and Agency (SVA). The primary CCMP code which appeared to be lacking was Construct Viable Arguments and Critique the Reasoning of Others (CACR). From a quantitative standpoint, over 65% of the pre-responses to the LAMP survey received a non-example coding in each of these areas, which was signified by an X (78% received a "EDCX" code, 74% received a "SVAX" code, and 66% received a "CACRX" code). In contrast, less than 14% of the pre-responses received a positive code for each area (13% received an "EDC" code, 13% received a "SVA" code, and 11% received a "CACR" code). It should be noted, as well, that each non-example code decreased in frequency by an average of 15% for each pre-response and post-response, some even as much as 22%. Likewise, each positive code increased in frequency between pre- and post-responses by an average of 13%. Thus, not only does there appear to be a deficit in the connection between equity pedagogy and mathematical practices, but there also seems to be a notable impact made by the pre-service Math Methods course in bridging this gap.

In addition to these data points, trends became evident during the analysis of the PST responses which received codes marked with an X in these areas. In terms of SVA, responders who fell in line with the non-example were not giving Maris the opportunity to voice her ideas.

They appeared to be set in their ways on this problem, demonstrated a narrow view of the potential student responses, and catered their teaching strategy to adjust Maris' thinking toward this singular view. In contrast, those with positive examples of this code explicitly sought an explanation from Maris regarding her concept of this problem and of the idea of rate of change in general. They not only allowed her to voice her ideas, but they also made a point to seek them out. EDC resembles SVA in that a diverse array of student voices are given merit in the classroom. As a result, EDC is a code that usually pairs with SVA for reasons of similarity. In terms of CACR, oftentimes responders who received CACRX codes read the question and Maris' answer, then assumed the labels that Maris would have placed on the graph had she used them. They evaluated her work and determined a strategy for teaching her based on these assumed labels, although they had not decided to speak to Maris to fully clarify her reasoning first. However, those who received a CACR code for their response provided Maris with the space to argue for her ideas and also oftentimes recognized that they would be better able to help Maris if they understood her thinking more fully.

Below is a sample answer for Maris' problem that has been coded, with the leftmost column representing the EPC codes and the middle column representing the CCMP codes. The sentence which has been bolded represents the multiple-choice response selected by the PST from those provided in the LAMP survey.

EDCX SVAX ESE	MSP CACRX	**Maris does not understand that the straight line indicates that the speed remains the same over time.** Maris shows that she doesn't understand that on the graph that if the line does not change it stays at a constant rate but is still moving. I believe Maris understands that when the line goes up that the speed increases or if it goes down that it decreases. However, she does not understand constant rate.
ETMP ETL	MM UTS	If I were to teach this to Maris, I would add labels, title and a scale to the graph so Maris can see how the numbers do not change on the scale. She would have a better understanding by seeing that at that point on the graph it does not change its speed but continues to move in distance.

Reflective prompts. In addition to the LAMP survey responses, the written responses to the reflective prompts provided to the PSTs were also analyzed. It is important to note that, in the case of Maris' problem, each of the PST responses was voluntary, seeing as the subjects were given the choice of which LAMP question they saw the most (as well as the least) growth in between their responses before taking their university Methods course and after completing it.

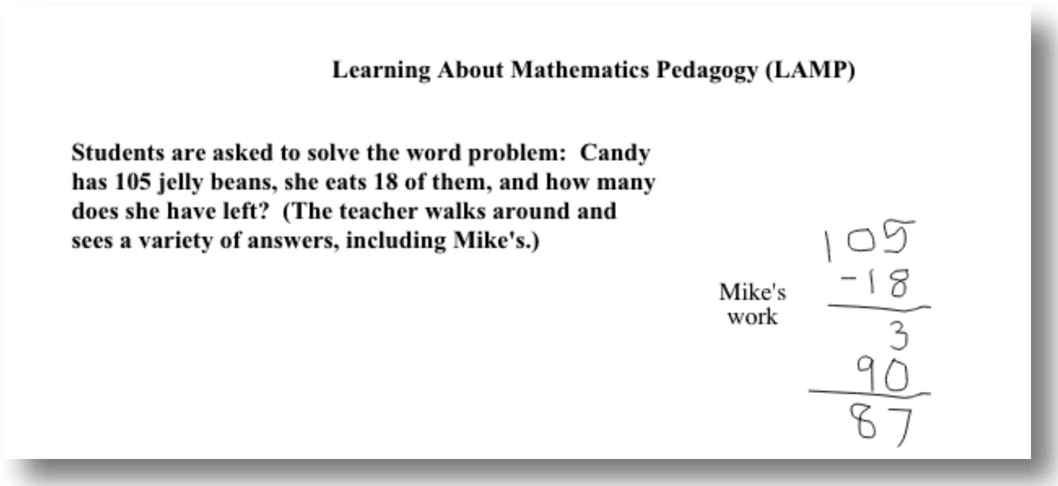
A number of PSTs identified Maris' problem as their perceived area of growth, first by identifying the faults in their reasoning for their pre-responses. For example, one PST wrote, "When I first completed this analysis, I thought about Maris's answer as wrong because it did not match what I thought a graph should represent." They then began to reflect on the ways in which they had grown throughout the semester in terms of their knowledge of pedagogy, mathematical understanding, knowledge of student thinking, and understanding of ways to attend to equity. Many chose to focus on their growth in content knowledge and how that impacted their attention to equity, saying, "In terms of mathematical understanding, I showed growth because now I am able to look at her graph and think more conceptually about what she is representing and consider other options." and, "I better understand mathematically the way graphs can be used to show data and can construct scenarios where her idea is correct because I can see with more clarity the approach she used." Thus, it is clear from these prompt responses that the PSTs recognized this growth in their mathematical understanding as having a positive influence on their abilities to attend to equity in their evaluations of students.

In addition, multiple PSTs identified Maris' problem as one in which they showed little to no growth. Many of these PSTs acknowledged the flaws in their thinking and identified specific changes they would make in the future to better incorporate equity, writing things like, "I need to allow the students to model their way of thinking." and, "In order for me to teach this better, I need to make sure I am prepared for any questions or answers students might ask or say during my teaching." In general, they also identified one key way to improve their instruction as enhancing their background knowledge of their content so as to be a better resource for their students, identify misconceptions more consistently, and (perhaps most importantly) anticipate different strategies students may use to solve problems. This is because, as one of the PSTs aptly responded, "There is not always just one method."

Mike

LAMP survey. The second problem chosen from the LAMP survey is one that focuses on an elementary algorithm, subtraction. The PSTs were provided with the information below, and they were then asked to represent Mike's thinking based on the work provided. The teachers were also asked what next steps they would take to further their students' understanding using Mike's work as a guide.

Mike's Subtraction Problem



Mike's work does not indicate that he is able to perform the traditional subtraction algorithm to achieve the desired result, but upon further inspection it appears that he has formulated his own algorithm which better represents his thinking as he engages with the process of subtraction mentally. It is important to note that, though Mike's method does not align with the algorithm that was most likely taught in his class, he was still able to obtain the correct solution. The assessment of this work would likely be dependent upon the teacher's agenda—was the teacher looking for correct use of the algorithm or rather correct logical reasoning in response to the problem? Though this is a much different topic than that of Maris' work, it remains evident that an equitable assessment of Mike's answer requires a complete knowledge of the content and a thorough analysis of the problem and solution method.

After analyzing the data, it is important to note that every PST response which was initially low in content knowledge and showed growth in this area also showed growth in the area of equity. The primary EPC codes which emerged as showing the most growth were Explicit Talk about Ways of Reasoning (ETR) and Fore-grounding Student Voice and Agency

(SVA), with the CCMP codes being Reason Abstractly and Quantitatively (RAQ) and Construct Viable Arguments and Critique the Reasoning of Others (CACR). From a quantitative standpoint, at least 47% of the pre-responses to the LAMP survey received non-example coding in each of these areas, as signified by an X (68% received an “ETRX” code, 56% received a “SVAX” code, 53% received a “RAQX” code, and 47% received a “CACRX” code). In contrast, less than 35% of the pre-responses received a positive code for each area, some as low as 6-8% (8% received an “ETR” code, 6% received a “SVA” code, 35% received a “RAQ” code, and 35% received a “CACR” code). It should be noted, as well, that each non-example code decreased in frequency by an average of 31% for each pre-response and post-response. Likewise, each positive code increased in frequency between pre- and post-responses by an average of 44%, some even demonstrated growth as high as 58%. Thus, not only does there appear to be a deficit in the connection between equity pedagogy and mathematical practices, but there also seems to be a notable impact made by the Math Methods course in bridging this gap.

In addition to this quantitative data, trends became evident during the analysis of the PST responses which received codes marked with an X in these areas. As far as ETR is concerned, PSTs whose response served as a non-example of this code overlooked the reasoning behind the subtraction algorithm and, in particular, Mike’s own personal algorithm. Often, they demonstrated a narrow view of the strategy as being a technique for solving the problem rather than considering the reasoning behind the use of the technique. However, those whose response served as a positive example of the code elaborated on the reasoning behind Mike’s response and mentioned that there are multiple ways of solving mathematics problems. Many of them emphasized understanding over procedures and sought out equitable ways to teach so that students had the opportunity to reason through problems on their own. In terms of SVA, responders who fell in line with the non-example were not providing Mike the opportunity to explain his thinking with regards to his personal algorithm that he developed apart from traditional subtraction. They appeared to be set in their ways on this problem, demonstrated a narrow view of the potential student strategies, and catered their teaching strategy to adjust Mike's procedure so that it aligned with the typical subtraction strategy. In contrast, those with positive examples of this code explicitly sought an explanation from Mike regarding his concept of this problem, even allowing him to explain his thinking to the class. For the CCMP codes, the responses that received a RAQX code did not recognize Mike's reasoning as valid and failed to encourage their students to reason through similar problems to Mike's. However, those who received a positive code in this area demonstrated a desire to foster a sense of mathematical reasoning in their classrooms and among their students by allowing them to discuss their own strategies for solving this and similar problems. In terms of CACR, oftentimes responders who received CACRX codes assumed that Mike had little to no concept of the subtraction algorithm and thus did not give him a chance to argue for the validity of his strategy. This signifies a failure on the part of the PSTs to speak to Mike and fully clarify his reasoning, as well as to incorporate other students into this potential teaching moment. On the other hand, those who received a CACR code for their response provided not only Mike but oftentimes other students with the space to argue for their ideas and even planned to allow them to explore additional strategies for concepts to be studied in future lessons.

Below is a sample answer for Mike's problem that has been coded, with the leftmost column representing the EPC codes and the middle column representing the CCMP codes. The rightmost column features the written response of the PST to this particular question on the LAMP survey.

266 SVAX EDCX	UTS	Mike subtracted upside down in the ones place. Mike subtracted 8-5 instead of 5-8, and then subtracted 10-1 to get 90. Then he subtracted 90-3 to get the answer of 87.
ETRX AUX ECTX	MM RAQX	I would model how to borrow from the hundreds and tens place. I think that Mike's problem is with borrowing. He might have felt unsure about 5-8, but knew that 8-5 was 3. It is obvious that he knows that the top number should actually go first, because that is what he did with 10-1. He may just be uncomfortable with borrowing so it would be good to model how to correctly borrow from the hundreds and tens place. I think that since the numbers worked out, he may have a hard time understanding why what he did was incorrect on his own, so that is why I chose modeling over exploration.

Reflective prompts. Similar to Maris' problem, the written responses to the reflective prompts provided to the PSTs for Mike's problem were also analyzed. However, in this case, the responders were required to comment on their perceived growth (or lack thereof) in terms of this problem, whereas this response was voluntary with Maris' problem. This provided the researchers with an increased quantity and variety of data for use in analysis.

In general, almost all of the PSTs recognized growth in at least one of the areas assessed: knowledge of pedagogy, mathematical understanding, knowledge of student thinking, and attention to equity. For the PSTs who identified growth throughout the semester in the area of mathematical understanding, many of them expressed a similar idea, writing, "I know the content better which means I can see the various ways to one solution (that) will help students learn." As the PSTs grew in content knowledge, they began to reflect on the importance of comprehension over algorithms, saying, "Procedure is acknowledged, but understanding is key." After realizing that "we do not all learn the same way" and "there are multiple ways of solving any problem," the PSTs began to choose more equitable responses to Mike's work, such as taking class time to allow students to explore different methods and explain their own personal strategies for solving. They justified this with the idea that, "since their conceptual understanding is secure, the math works." Upon realizing that his understanding was correct, they began asking themselves questions such as, "Who am I to change his way of thinking?" As the PSTs reflected on how they could maintain their equity practices in the classroom, they expressed ideas like, "I need to continue to develop mathematical understanding…I don't want my students or myself to lose the thinking behind the math problems." One PST summed up their learning in this course by writing a reminder that is important for everyone in the field of education, "Educators are responsible for teaching their students how to think so they can accomplish anything, not teaching how to do so they can accomplish little." Thus, it is clear from the PST prompt responses that these PSTs recognized the growth in their mathematical understanding as having a positive influence on their abilities to attend to equity in their evaluations of students.

Discussion

This analysis presents a number of important conclusions and implications for future study on the topic of equity in mathematics, many of which are discussed below. However, in order to draw conclusions in the most holistic way, it is important to also consider the limitations of this study, as well.

Limitations. This study is limited by four main factors which were out of the control of the research team but nevertheless influenced the outcome of the study, these factors being subjects, location, procedure, and content. By surveying PSTs at a particular Research I institution, the research completed in this study is limited to the results gained from the PSTs at this select university, rather than a wider range of PSTs across a variety of campuses. Additionally, the featured PSTs were members of the same cohort and thus taught by the same instructor, which begs the question of whether or not the results of this study would have been impacted if PSTs from another professor and/or cohort were also surveyed in the same way. The nature of the data collection also serves a limitation of the study, considering the PSTs did not participate in an in-person interview process but rather responded to the written questions of the LAMP survey tool and reflective prompts tool. There is a chance that, if the researcher would have chosen to complete in-person interviews of the subjects, this difference in procedure could have influenced the outcome of the study. In addition, the subjects of this study were chosen from an Early Childhood Education (ECE) program, which limits the level of mathematics that is covered in the study and thus narrows the scope of the results. Finally, the analysis focuses primarily on the PST responses to two select student work samples, which also serves as a significant limitation of the content being covered in this study. These limitations are important to note in light of the results and conclusions of this study along with the potential for further investigation and analysis in this area, as detailed below.

Conclusions. The data collected suggests these PSTs were not instinctively choosing to seek out and give weight to the arguments of their own students. Instead, it appears that, prior to completing the required Math Methods course, many were using a narrow perspective in approaching their own mathematical content as well as in interpreting their students' logical reasoning without input from the students themselves. In particular, the survey results suggest that the subjects of the study were struggling to demonstrate their ability to encourage input from a diverse array of mathematical competencies as well as give students voice and incorporate their ideas in future lessons. In addition, these PSTs seemed to struggle with demonstrating certain mathematical practices in their assessments, including evaluating their students on their ability to construct arguments and critique those of others. However, these results improved significantly upon a second administration of the survey and reflective prompts tool following a Math Methods course taken by the PSTs as part of their undergraduate program. We conclude that the PSTs' initial perspective came as the result of an incomplete content knowledge, given they were more inclined to make equitable choices in their responses to students' work when they themselves demonstrated a deeper understanding of the content that was being taught. Their initial perspective could also be related to their lack of familiarity with or understanding of equity pedagogy, especially in the context of mathematical content. Strengthening both the mathematics content courses and equity education of the PSTs are two methods for resolving this disparity, as the results of the study strongly support that an increase in content knowledge and mathematical understanding correlate with an increase in equitable practices in the classroom.

Future Study. It is important to consider the potential for further study in light of the limitations of presented in this paper. For instance, since this study was limited by surveying PSTs at a particular Research I institution, a future study could involve continuing this research with wider range of PSTs across a variety of campuses. This would also address the limitation of choosing PSTs who are members of the same cohort and thus taught by the same instructor, as in the case of this study. The nature of the data collection also serves a limitation of the study, so a future project could incorporate in-person interviews with subjects, which would influence the qualitative results of this study in particular. In addition, the subjects of this study were chosen from an ECE program; so, to offset the limitation of the level of mathematics that is covered in this study, a future study could feature PSTs from various programs and mathematical content areas, particularly those levels of education in which mathematics becomes the primary focus (such as secondary education). Thus, it is possible for the limitations of this study to serve as a basis for future data collection and analysis in this area.

This research could also be furthered in a number of ways apart from the tools used in this particular study. Equity pedagogy also addresses issues such as discrimination based on race, religion, gender, sexuality, and various other identities, so a future study could seek to analyze how these issues affect the instruction and assessment of students, especially in a math context. This is particularly important because, in society today, there is a disparity between who has access to education and even whose ideas are considered valid and worthwhile in the field. The details of the PSTs' and the students' identities were not provided as part of this research study, which limited the scope of this area of research. However, if these details were to be disclosed in a future study, this could lead to a deeper analysis of the impact of identities on justice and power roles in the classroom on the part of teachers and students alike. It also could expand the study to consider the idea of teacher noticing, which involves the ways in which a teacher attends to students' identities and builds on students' funds of knowledge in order to validate their learning experiences (Chao, Murray, & Gutiérrez, 2014). This is an important note to potentially include in the coursework for future Math Methods courses such as the one featured as part of this research, as well. In sum, this study seeks to answer the call for increased equity research in the domain of mathematics while also issuing a call of its own for continued research in this field in order to foster more equitable classrooms in the future.

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